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Report No. RR-8

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Computer Laboratory
Research Division
Research and Engineering Directorate

DIGITAL COMPUTER PROGRAM FOR ACCELERATION PERFORMANCE, TRACKED VEHICLES

by

Robert Arno

25 January 1960

Contract No. DA-20-089-ORD-39246

Project No. 5510.11.270

D/A Project No. 5W72-01-001

Reviewed Fred Radke

Approved S M Zeller

Ordnance Tank-Automotive Command
Detroit Arsenal
Center Line, Michigan

Report No. RR-8

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D I G I T A L C O M P U T E R P R O G R A M
F O R
A C C E L E R A T I O N P E R F O R M A N C E,
T R A C K E D V E H I C L E S

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Robert Arno

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Reviewed Fred Brodko

Approved S. M. Zulli

Ordnance Tank-Automotive Command
Detroit Arsenal
Center Line, Michigan

ABSTRACT

A general computer program was written for the Electrodata 204 "Datatron" Digital Computer to calculate acceleration performance and related characteristics of tracked vehicles.

Vehicle performance is determined at prescribed time intervals during acceleration from standstill to maximum velocity. Other additional data supplied by this program are vehicle speed, distance traveled, time of travel, sprocket torque, tractive effort, rolling resistance, drawbar pull, and acceleration.

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PROJECT TITLE: DIGITAL COMPUTER PROGRAM FOR ACCELERATION PERFORMANCE, TRACKED VEHICLES

INTRODUCTION:

This report presents a high-speed computer program for determining maximum acceleration performance of tracked vehicles on level or grade terrain.

Data resulting from this program are vehicle speed, distance traveled, time of travel, sprocket torque, tractive effort, rolling resistance, drawbar pull, and acceleration.

OBJECT:

Develop a digital computer program for rapid and accurate solution of vehicle acceleration performance.

SUMMARY:

1. Study of vehicle acceleration is a specific application of Newton's third law of motion ($F = MA$). Synthesis of the essential force and mass factors describes acceleration performance of track type vehicles as equal to the ratio of vehicle drawbar pull and equivalent mass.

$$F = MA$$

$$A = \frac{F}{M} = \frac{\text{Vehicle Drawbar Pull}}{\text{Vehicle Mass @ Acceleration}}$$

$$= \frac{\text{Tractive Effort - Resistance}}{\text{Equivalent Mass}}$$

$$= \frac{[(T_T \times R_{FD} \times E_{FD})/PDS.] - [Wt(\text{Sine } \theta) + RR]}{(Wt/g) \times (1.07 + .0025\ \zeta^2)}$$

T_T = Transmission Torque

R_{FD} = Final Drive Ratio

E_{FD} = Final Drive Efficiency

PDS = Pitch Diameter of Sprocket

Wt = Vehicle Weight

θ = Grade Angle

RR = Rolling Resistance

g = Gravity

ζ = Gear Reduction

2. Data of velocity, time, and distance are automatically plotted on graphs of time vs. velocity, time vs. distance, and distance vs. velocity.

3. Accuracy of the program was established by comparing calculated results of the T113E1 with actual field tests. Field tests and calculated acceleration performance are illustrated in Figure A1, Appendix A.

4. Equipment necessary to operate the program is the main "Datatron" computer and console, a magnetic tape unit, a high-speed punch and/or wide carriage Flexowriter with format control, and the PACE data-plotter.

CONCLUSIONS AND RESULTS:

1. In the course of this study, it was necessary to use a mathematical model representing standard tracked vehicle design. Unique vehicle designs may require program modification to reflect adequate mathematical precision.

2. Final results correlate closely to actual field tests for accurate input data. The program offers an opportunity to study changes in over-all vehicle performance by changing characteristics of individual systems.

3. Accuracy of results largely depends on the validity of input data. Program correlation with experimental data taken in the field indicates accuracy within limits of ±5%. Program solution requires approximately 11 minutes of machine time and 18 minutes for data printout.

BACKGROUND INFORMATION:

1. Major components of the mathematical model presented in Summary, para. 1., other than those of basic vehicle mechanics, are as described by Jaroslav J. Taborek in "Mechanics of Vehicles".[1]

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1. Available at Reader Service Department, MACHINE DESIGN, Penton Building, Cleveland 3, Ohio.

2. Mr. Taborek's inertia resistance formula, $\gamma = 1 + (a + .0025 \zeta^2)$[1]., gives γ as an equivalent mass, (a) as a constant reflecting inertia resistance of the track, and ζ as a gear reduction between engine and sprocket. The equivalent mass is a variable that takes into consideration acceleration of rotating masses within the vehicle.

---

1. Page 39 of "Mechanics of Vehicles".

FLOW CHART:

The flow chart (Figure 1) is a graphic explanation of the program. The program sequence and operational steps are shown together with the method of using input data and logic of decision branching. Figure 2 is a detailed representation of the digital computer program describing the solution of vehicle acceleration.

EQUATION FLOW CHART
TRACKED VEHICLE ACCELERATION PROGRAM

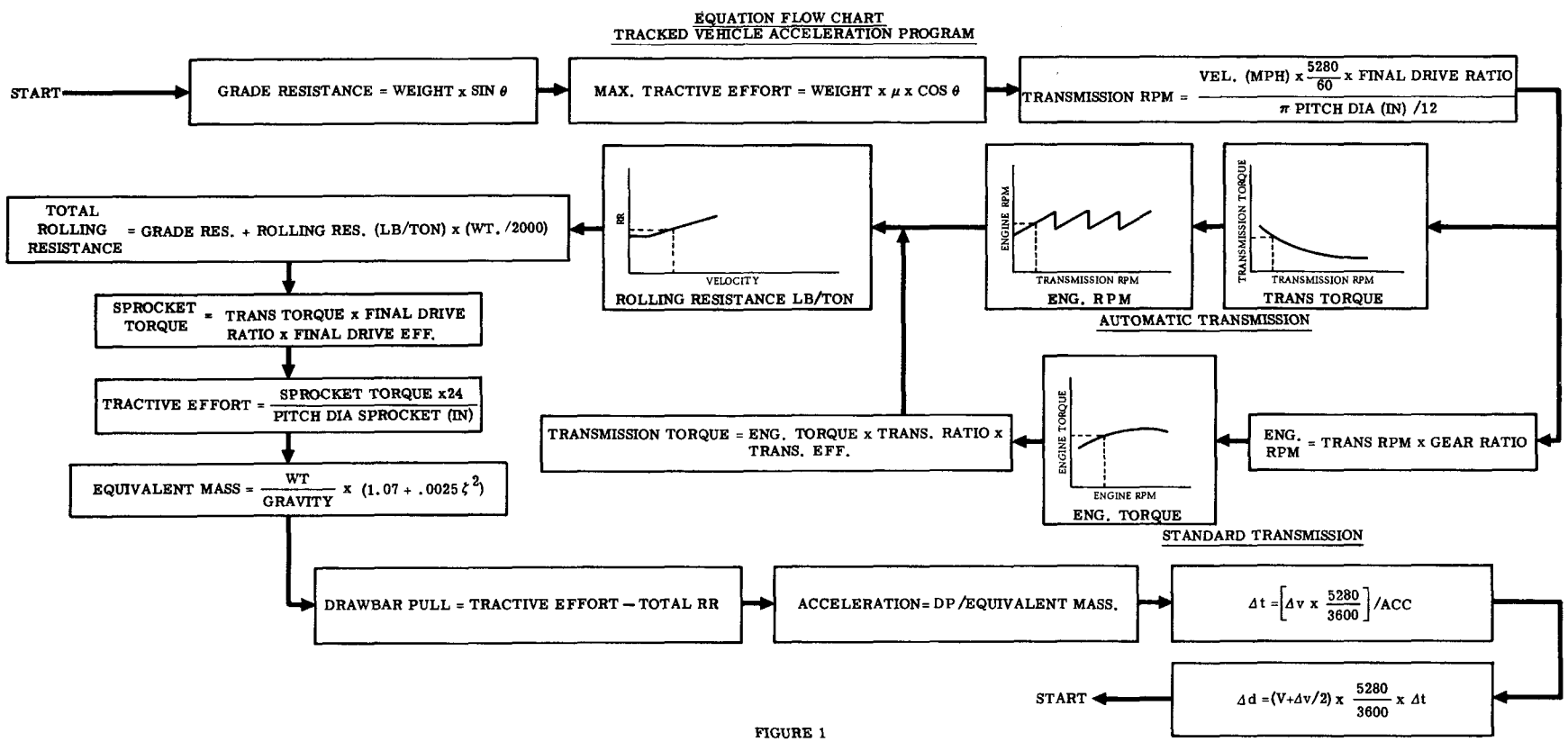

FIGURE 1

DIGITAL COMPUTER FLOW CHART
TRACKED VEHICLE ACCELERATION PROGRAM

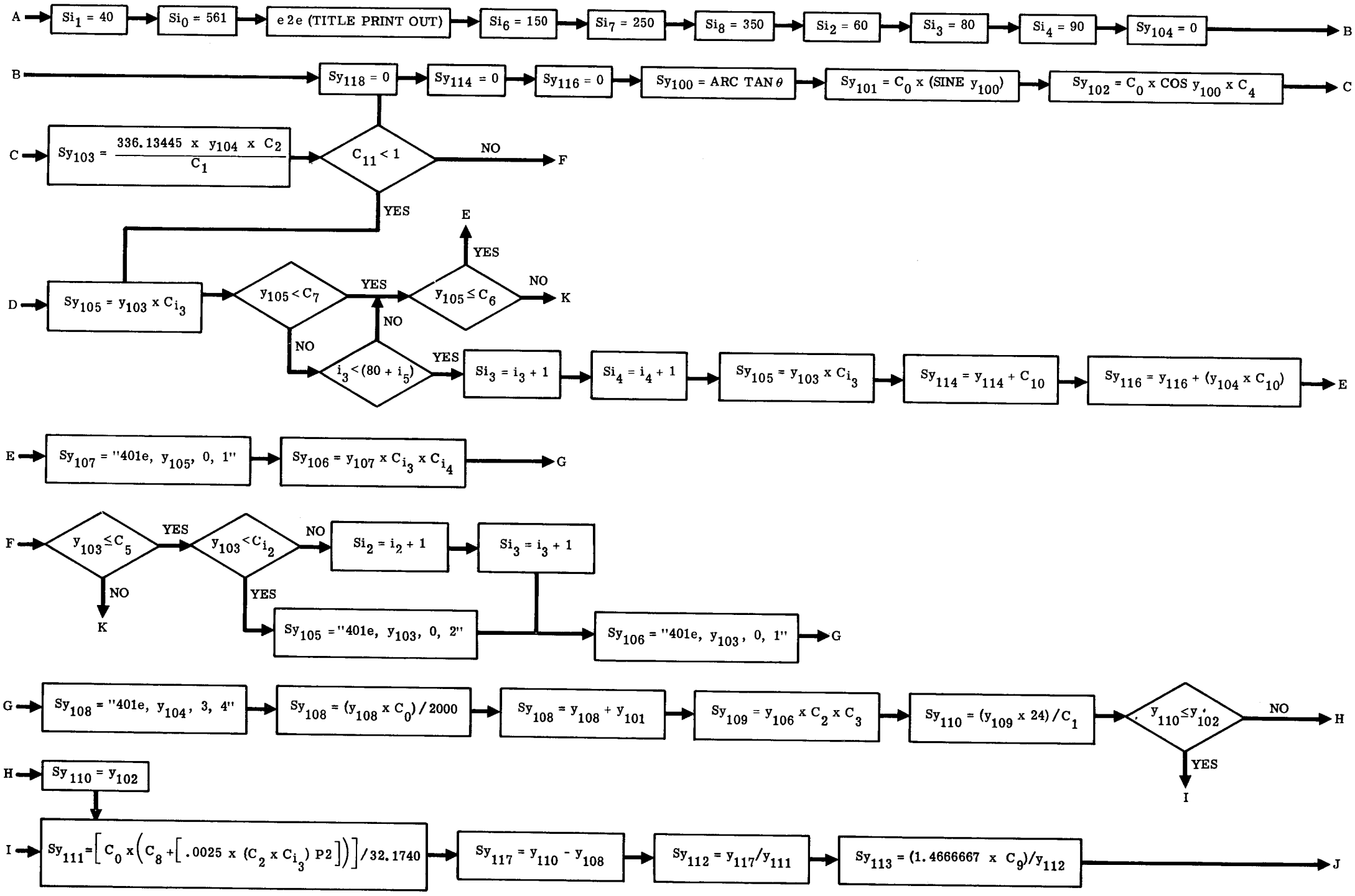

FIGURE 2 (PART 1)

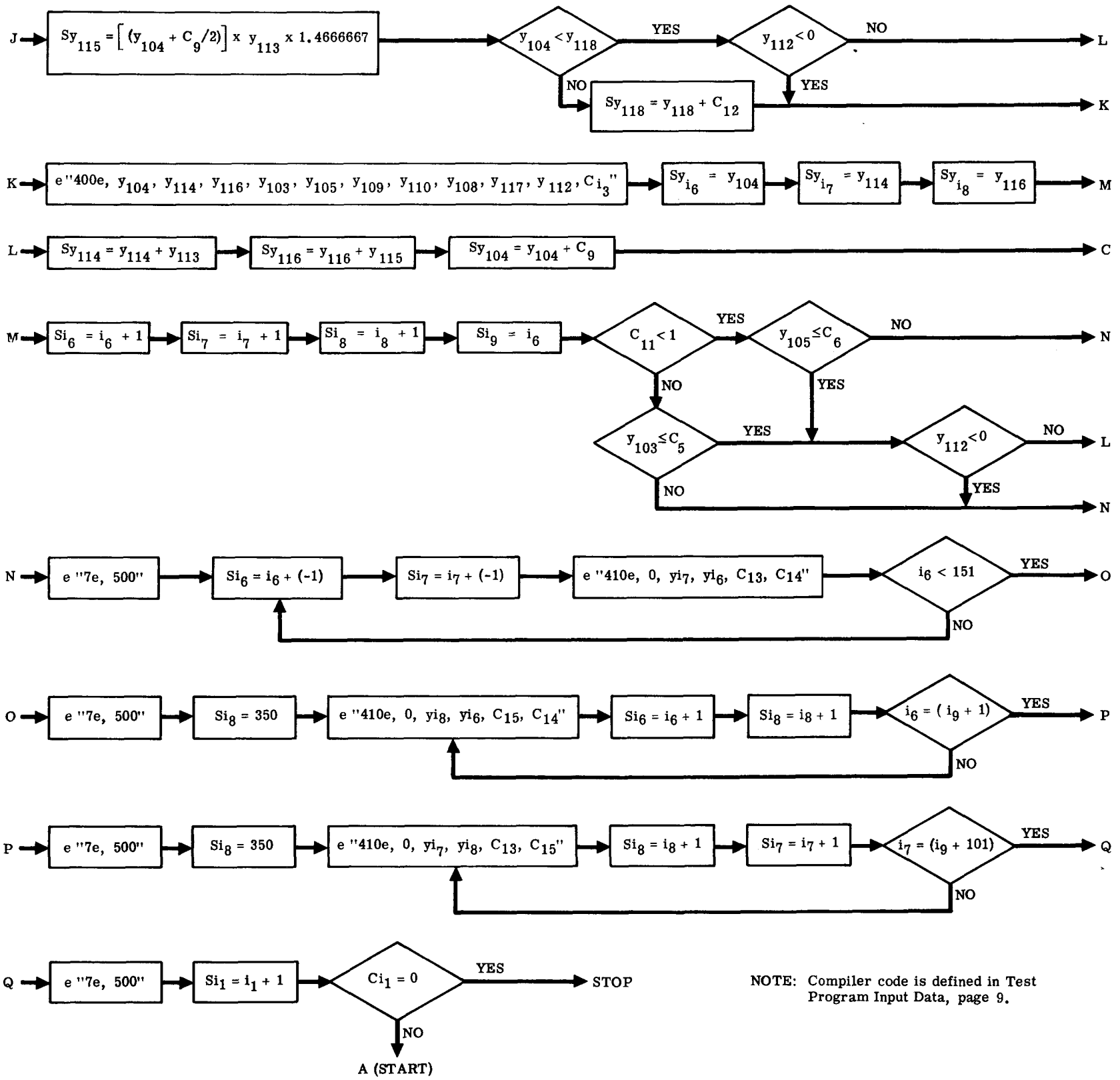

FIGURE 2 [PART 2]

NOTE: Compiler code is defined in Test Program Input Data, page 9.

TEST PROGRAM INPUT DATA:

Test program input data are illustrated in Appendix B. Problem solution and data printout require the use of 10 subroutines. Subroutine numbers and descriptions are listed in the same order as they appear on the program printout (Appendix C).

410	Dataplotter routine
007	Automatic high-speed tape feed
400	Data printout
401	Linear interpolation
099	Error routine
204	Cosine θ
203	Sine θ
206	Arctan θ
002	Alphanumeric printout
FPA.	Floating point arithmetic

Compiler code, description and storage locations for program variables and constants are as follows (these compiler codes are shown in the flow chart of Figure 2):

Compiler Notation	Storage Location	Description
i_1	0001	Variables 40-59 subscript for grades in % slope
i_2	0002	Variables 60-70 subscript for shift rpm
i_3	0003	Variables 80-89 subscript for transmission ratios
i_4	0004	Variables 90-99 subscript for standard transmission efficiencies
i_5	0005	Constant, one less than the number of gears, for standard transmission only

Compiler Notation	Storage Location	Description
i_6	0006	Variables 150-249 subscript for Dataplotter velocity
i_7	0007	Variables 250-349 subscript for Dataplotter time
i_8	0008	Variables 350-449 subscript for Dataplotter distance
i_9	0009	Subscript for Dataplotter index
y_0 ↓ y_{99}	0010 ↓ 0109	Alphanumeric printout of title and column headings
y_{100}	0110	Tan. of slope
y_{101}	0111	Grade resistance, lb force
y_{102}	0112	Max. tractive effort
y_{103}	0113	Transmission rpm
y_{104}	0114	Velocity mph
y_{105}	0115	Engine rpm
y_{106}	0116	Transmission torque, lb-ft
y_{107}	0117	Engine torque, lb-ft
y_{108}	0118	Rolling resistance, lb/ton and lb force
y_{109}	0119	Sprocket torque, lb-ft
y_{110}	0120	Tractive effort, lb force
y_{111}	0121	Equivalent mass, slugs
y_{112}	0122	Acceleration, ft/sec/sec

Compiler Notation	Storage Location	Description
y_{113}	0123	Δ t, sec.
y_{114}	0124	t, sec.
y_{115}	0125	Δ d, ft
y_{116}	0126	d, ft
y_{117}	0127	Drawbar pull, lb force
y_{118}	0128	Velocity printout index
y_{150} ↓ y_{249}	0160 ↓ 0259	Storage locations for Data-plotter velocity
y_{250} ↓ y_{349}	0260 ↓ 0359	Storage locations for Data-plotter time
y_{350} ↓ y_{449}	0360 ↓ 0459	Storage locations for Data-plotter distance
c_0	0461	Vehicle weight, lb
c_1	0462	Pitch diameter of sprocket, in.
c_2	0463	Final drive ratio
c_3	0464	Final drive efficiency
c_4	0465	Coefficient of frictions, %
c_5	0466	Max. transmission speed, rpm (auto. only)
c_6	0467	Max. engine speed, rpm (std. trans. only)

Compiler Notation	Storage Location	Description
c_7	0468	Engine shift speed, rpm (std. trans. only)
c_8	0469	Equiv. mass factors for track (1.07)
c_9	0470	Δ V, mph
c_{10}	0471	Gear shift time, sec (std. trans. only)
c_{11}	0472	Trans. decision (1 for auto, 0 for std.)
c_{12}	0473	Printout interval, mph
c_{13}	0474	Maximum time, sec.
c_{14}	0475	Maximum velocity, mph
c_{15}	0476	Maximum distance, ft
ci_1	0501-0520	Grade, % slope
ci_2	0521-0540	rpm for shift to next gear (auto. only)
c_{80} ↓ c_{89}	0541 ↓ 0550	Transmission ratio
c_{90} ↓ c_{99}	0551 ↓ 0560	Std. transmission only, corres. efficiency for above gear ratios
c_{100} ↓ c_{119}	0561 ↓ 0580	Std. trans.--engine speed, rpm Auto. trans.--trans. speed, rpm

Compiler Notation	Storage Location	Description
c_{120}	0581	Std. trans.--corres. eng. torque, lb-ft Auto. trans.--corres. trans. torque, lb-ft
c_{139}	0600	
c_{140}	0601	Auto. trans. only--corres. eng. speed
c_{159}	0620	
c_{160}	0621	Velocity points on rolling resistance curve, mph
c_{179}	0640	
c_{180}	0641	Rolling resistance points, lb/ton
c_{199}	0660	

STATEMENT AND PROGRAM PRINTOUT:

Statements of the program printout are in Appendix C.

Written by:

Robert D. Arno
Computer Laboratory

Reviewed by:

Fred Pradko
Chief, Computer Laboratory

Approved by:

S. H. Fuller
Chief, Research Division
Res and Engr Directorate

TABLE A1

COMPUTED PROGRAM RESULTS (T113E1)

VEHICLE PERFORMANCE PROJECTIONS (TIME DISTANCE AND TIME SPEED)

VELOCITY MPH	TIME SEC	DIST FT	TRANSMISSION RPM	ENGINE RPM	SPROCKET TORQUE	TRACTIVE EFFORT	ROLLING RESISTANCE	D.B.P.	ACCELERATION FT/SEC/SEC	GEAR RATIO
+.00000000 -00	+.00000000 -00	+.00000000 -00	+.00000000 -00	+.23600000 +04	+.13420833 +05	+.16240000 +05	+.90016000 +03	+.15339840 +05	+.89665362 +01	+ 52960000 +01
+ 10000000 +01	+.16803837 -00	+.12486612 -00	+.73877582 +02	+.24141769 +04	+.11819715 +05	+.14465739 +05	+.90016000 +03	+.13565579 +05	+.79294344 +01	+.52960000 +01
+.20000000 +01	+.36020277 -00	+.55026763 -00	+.14775517 +03	+.24683538 +04	+.10218597 +05	+.12506186 +05	+.90016000 +03	+.11606026 +05	+.67840246 +01	+.52960000 +01
+ 30000000 +01	+.58636387 -00	+.13831795 +01	+.22163275 +03	+.25225307 +04	+.86174794 +04	+.10546634 +05	+.90016000 +03	+.96464740 +04	+ 56386154 +01	+.52960000 +01
+.40000000 +01	+ 86117788 -00	+ 27992825 +01	+.29551034 +03	+.25767076 +04	+.70163611 +04	+.85870810 +04	+.90016000 +03	+.76869210 +04	+.44932056 +01	+.52960000 +01
+.50000000 +01	+ 12010234 +01	+.50471866 +01	+.36938792 +03	+.26307066 +04	+.61062025 +04	+.74731698 +04	+.90016000 +03	+.65730098 +04	+.38420955 +01	+.52960000 +01
+.60000000 +01	+.15998793 +01	+.82709010 +01	+.44326551 +03	+.23658551 +04	+.53905739 +04	+.65973365 +04	+.92302855 +03	+.56743079 +04	+.33167808 +01	+.52960000 +01
+.70000000 +01	+.20433289 +01	+.12498912 +02	+.51714309 +03	+.27625132 +04	+.53569751 +04	+.65562162 +04	+.94589710 +03	+.56103191 +04	+.32793777 +01	+.52960000 +01
+.80000000 +01	+.24918509 +01	+.17433123 +02	+.59102065 +03	+.31619912 +04	+.52532167 +04	+.64292299 +04	+.96876570 +03	+.54604642 +04	+.31917836 +01	+.52960000 +01
+.90000000 +01	+.29656571 +01	+.23345148 +02	+.66489826 +03	+.35775527 +04	+.47492991 +04	+.58125022 +04	+.99163425 +03	+.48208679 +04	+.28179229 +01	+.52960000 +01
+.10000000 +02	+.35046249 +01	+.30861544 +02	+.73877582 +03	+.39931140 +04	+.42453816 +04	+.51957751 +04	+.10145028 +04	+.41812723 +04	+.24440626 +01	+.52960000 +01
+.11000000 +02	+.40659204 +01	+.39491268 +02	+.81265344 +03	+.29532356 +04	+.36348460 +04	+.44485621 +04	+.10373714 +04	+.34111907 +04	+.27123387 +01	+.38100000 +01
+.12000000 +02	+.46164399 +01	+.48780284 +02	+.88653100 +03	+.32658835 +04	+.34589133 +04	+.42332442 +04	+.10602399 +04	+.31730043 +04	+.25229496 +01	+.38100000 +01
+.13000000 +02	+.52091052 +01	+.59649970 +02	+.96040861 +03	+.35785317 +04	+.32829801 +04	+.40179256 +04	+.10831085 +04	+.29348171 +04	+.23335599 +01	+.38100000 +01
+.14000000 +02	+.58509072 +01	+.72362524 +02	+.10342861 +04	+.38911794 +04	+.31070478 +04	+.38026082 +04	+.11059771 +04	+.26966311 +04	+.21441712 +01	+.38100000 +01
+.15000000 +02	+.65390991 +01	+.86999600 +02	+.11081637 +04	+.28842930 +04	+.26168883 +04	+.32027189 +04	+.11288457 +04	+.20738732 +04	+.20455008 +01	+.26900000 +01
+.16000000 +02	+.72693618 +01	+.10360576 +03	+.11820413 +04	+.30946506 +04	+.25148549 +04	+.30778438 +04	+.11517142 +04	+.19261296 +04	+.18997785 +01	+.26900000 +01
+.17000000 +02	+.80567765 +01	+.12266684 +03	+.12559189 +04	+.33050083 +04	+.24128214 +04	+.29529685 +04	+.11745828 +04	+.17783857 +04	+.17540558 +01	+.26900000 +01
+.18000000 +02	+.89110530 +01	+.14459991 +03	+.13297965 +04	+.35153659 +04	+.23107881 +04	+.28280935 +04	+.11974514 +04	+.16306421 +04	+.16083335 +01	+.26900000 +01
+.19000000 +02	+.98446062 +01	+.16993825 +03	+.14036741 +04	+.37257235 +04	+.22087546 +04	+.27032182 +04	+.12203198 +04	+.14828984 +04	+.14626111 +01	+.26900000 +01
+.20000000 +02	+.10873665 +02	+.19937899 +03	+.14775517 +04	+.39360811 +04	+.21067212 +04	+.25783430 +04	+.12431884 +04	+.13351546 +04	+.13168885 +01	+.26900000 +01
+.21000000 +02	+.12049464 +02	+.23475411 +03	+.15514293 +04	+.29082561 +04	+.18636623 +04	+.22808717 +04	+.12660570 +04	+.10148147 +04	+.11312579 +01	+.19360000 +01
+.22000000 +02	+.13378186 +02	+.27666497 +03	+.16253068 +04	+.30668482 +04	+.18038005 +04	+.22076089 +04	+.12889256 +04	+.91868330 +03	+.10240960 +01	+.19360000 +01
+.23000000 +02	+.14849877 +02	+.32524527 +03	+.16991844 +04	+.32254406 +04	+.17439387 +04	+.21343461 +04	+.13117942 +04	+.82255190 +03	+.91693423 -00	+.19360000 +01
+.24000000 +02	+.16499045 +02	+.38210478 +03	+.17730620 +04	+.33840329 +04	+.16840769 +04	+.20610833 +04	+.13346628 +04	+.72642050 +03	+.80977239 -00	+.19360000 +01
+.25000000 +02	+.18374421 +02	+.44951683 +03	+.18469396 +04	+.35426253 +04	+.16242150 +04	+.19878204 +04	+.13575314 +04	+.63028900 +03	+.70261045 -00	+.19360000 +01
+.26000000 +02	+.20548040 +02	+.53084176 +03	+.19208172 +04	+.37012176 +04	+.15643532 +04	+.19145576 +04	+.13803998 +04	+.53415780 +03	+.59544883 -00	+.19360000 +01
+.27000000 +02	+.23132947 +02	+.63135314 +03	+.19946947 +04	+.38598097 +04	+.15044915 +04	+.18412950 +04	+.14032684 +04	+.43802660 +03	+.48828722 -00	+.19360000 +01
+.28000000 +02	+.26321759 +02	+.76003643 +03	+.20685724 +04	+.29099281 +04	+.13810111 +04	+.16901716 +04	+.14261370 +04	+.26403460 +03	+.31573452 -00	+.13900000 +01
+.29000000 +02	+.31244227 +02	+.96589723 +03	+.21424499 +04	+.30067877 +04	+.13536890 +04	+.16567330 +04	+.14490056 +04	+.20772740 +03	+.24840195 -00	+.13900000 +01
+.30000000 +02	+.37611480 +02	+.12415567 +04	+.22163275 +04	+.31036475 +04	+.13263668 +04	+.16232943 +04	+.14718742 +04	+.15142010 +03	+.18106927 -00	+.13900000 +01
+.31000000 +02	+.46636515 +02	+.16456158 +04	+.22902051 +04	+.32005073 +04	+.12990447 +04	+.15898557 +04	+.14947428 +04	+.95112900 +02	+.11373670 -00	+.13900000 +01
+.32000000 +02	+.62242759 +02	+.23676184 +04	+.23640827 +04	+.32973671 +04	+.12717225 +04	+.15564171 +04	+.15176112 +04	+.38805900 +02	+.46404381 -01	+.13900000 +01
+.33000000 +02	+.13561702 +03	+.58804401 +04	+.24379603 +04	+.33942268 +04	+.12444003 +04	+.15229784 +04	+.15404798 +04	-.17501400 +02	-.20928303 -01	+.13900000 +01

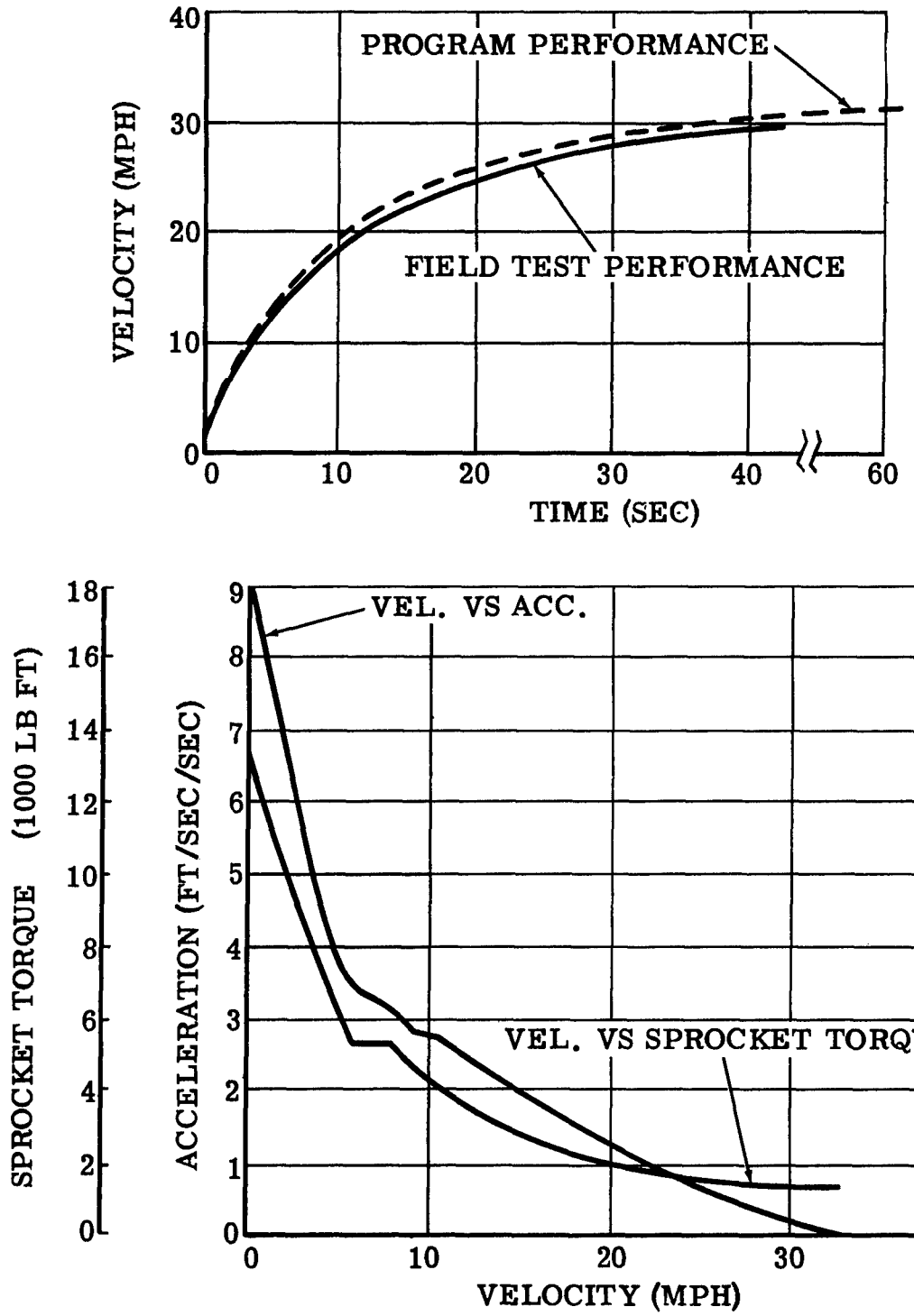

FIGURE A1. DIGITAL COMPUTER PROGRAM EVALUATION
T113E1 CORRELATION

APPENDIX B

COMPUTER PROGRAM INPUT DATA (T113E1)

APPENDIX B

COMPUTER PROGRAM INPUT DATA (T113E1)

Vehicle weight		23,200 lb	
Pitch diameter sprocket		19.61 in.	
Final drive ratio		4.31:1	
Final drive efficiency		82.75 %	
Coefficient of friction		.7	
Maximum transmission speed		4,000 rpm	
Equiv. mass factor for track		7 %	
Incremental increase in velocity		.5 mph	
Trans. decision constant		1 (auto. trans.)	
Printout interval		1 mph	
Maximum time		99 sec	Constants for full scale deflection in automatic plotting routine
Maximum velocity		99 mph	
Maximum distance		9,900 ft	
Shift speeds:	to 2nd	750 rpm	
	to 3rd	1,070 rpm	
	to 4th	1,500 rpm	
	to 5th	2,060 rpm	
	to 6th	2,900 rpm	

APPENDIX B (Cont'd.)

Transmission Ratios:		
	1st	5.296:1
	2nd	3.810:1
	3rd	2.690:1
	4th	1.936:1
	5th	1.390:1
	6th	1.000:1

Transmission Speed (rpm)	Corres. Trans. Torque (lb-ft)	Corres. Engine Speed (rpm)
4,000	194	4,000
2,901	272	2,900
2,900	301	4,000
2,061	388	2,900
2,060	407	4,000
1,501	534	2,800
1,500	582	4,000
1,061	752	2,750
1,060	854	4,000
741	1,067	2,650
740	1,188	4,000
580	1,494	3,100
431	1,513	2,300
430	1,513	2,675
300	1,940	2,580
0	3,763	2,360

Rolling Resistance Data:

Rolling Resistance (lb/ton)	Corres. Vehicle Velocity (mph)
146.6	40
77.6	5
77.6	0

APPENDIX B

COMPUTER PROGRAM INPUT DATA PRINTOUT (T113E1)

```
+0000000461
+5523200000
+5219610000
+5143100000
+5082750000
+5070000000
+5440000000
+0000000000
+0000000000
+5110700000
+5050000000
+0000000000
+5110000000
+5110000000
+5299000000
+5299000000
+5499000000
+0000000501
+0000000000
+0000000000
+0000000521
+5375000000
+5410700000   Shift rpm
+5415000000
+5420600000
+5429000000
+7070000000
+0000000541
+5152960000
+5138100000   Transmission
+5126900000      ratios
+5119360000
+5113900000
+5110000000
+0000000565
+5440000000
+5429010000   Transmission
+5429000000      rpm
+5420610000
+5420600000
+5415010000
+5415000000
+5410610000
+5410600000
+5374100000
+0000000585
+5319400000
+5327200000   Transmission Torque
+5330100000      x .97 lb. ft.
+5338800000
+5340700000
+5353400000
+5358200000
+5375200000
+5385400000
+5410670000
+5411880000
+5414940000
+5415130000
+5415130000
+5419400000
+5437630000
+0000000605
+5440000000
+5429000000   Engine speed rpm
+5440000000
+5429000000
+5440000000
+5428000000
+5440000000
+5427500000
+5440000000
+5426500000
+5440000000
+5431000000
+5423000000
+5426750000
+5425800000
+5423600000
+0000000654
+0000000000
+0000000000
+0000000000
+0000000000
+5314660000
+5277600000   R.R. lb/ton
+5277600000
+0000000634
+0000000000
+0000000000
```

+5374000000	+0000000000	
+5358000000	+0000000000	
+5343100000	+5240000000	MPH
+5343000000	+5150000000	
+5330000000	+0000000000	
+0000000000	+0000080000	

APPENDIX C

COMPUTER PROGRAM PRINTOUT

A statement and program printout is a product of the Purdue Compiler. Each compiler statement is printed out, and the computer commands necessary to perform the statement are printed below it. The four digit number to the extreme left is the command cell location. The algebraic sign and ten digit number is the computer command.

APPENDIX C

COMPUTER PROGRAM PRINTOUT - ACCELERATION PERFORMANCE OF TRACKED VEHICLES

REMARKS

```
i 0000
y0  0010
c0  0461
s0  0662
b0  0740

 410 e  03  3520  0537

 007 e  01  3500  0000

 400 e  02  3460  0519

 401 e  04  3380  0531

 099 e  01  3360  0460

 204 e  05  3260  0472

 203 e  05  3160  0467

 206 e  06  3040  0525

 002 e  01  3020  0536

f.p.a.e 18  3580  0501

2si1=40  f

 0740  + 0000 64 7019
 0741  + 0000 02 0001

1si0=561 f

 0742  + 0000 64 7018
 0743  + 0000 02 0000

0e"2e,990010" f

 0744  + 0000 64 7017
 0745  + 0100 21 3020
```

Computer preparation

Title and column heading printout

```
0si6=150 f

 0746  + 0000 64 7016
 0747  + 0000 02 0006

0si7=250 f

 0748  + 0000 64 7015
 0749  + 0000 02 0007

0si8=350 f

 0750  + 0000 64 7014
 0751  + 0000 02 0008
 0752  + 0000 30 0760
 0753  + 0200 21 3060
 0754  + 0000 00 0350
 0755  + 0000 00 0250
 0756  + 0000 00 0150
 0757  + 0000 99 0010
 0758  + 0000 00 0561
 0759  + 0000 00 0040

3si2=60  f

 0760  + 0000 64 7019
 0761  + 0000 02 0002

4si3=80  f

 0762  + 0000 64 7018
 0763  + 0000 02 0003

5si4=90  f

 0764  + 0000 64 7017
 0765  + 0000 02 0004

6sy104=0.f

 0766  + 0000 64 7016
 0767  + 0000 02 0114

0sy118=0.f

 0768  + 0000 64 7016
 0769  + 0000 02 0128
```

Computer preparation

```
0sy114=0.f

 0770  + 0000 64 7016
 0771  + 0000 02 0124

0sy116=0.f

 0772  + 0000 64 7016
 0773  + 0000 02 0126

7sy100="206e,ci1"  f  Find θ from tan θ

 0774  + 0000 72 0001
 0775  + 0000 30 0780
 0776  - 0000 00 0000
 0777  + 0000 00 0090
 0778  + 0000 00 0080
 0779  + 0000 00 0060

 0780  - 0000 64 0461
 0781  + 0100 21 3040
 0782  + 0000 02 0110

8sy101=c0x("203e,y100") f  Grade resistance

 0783  + 0000 64 0110
 0784  + 0100 21 3160
 0785  + 0461 21 3600
 0786  + 0000 02 0111

9sy102=c0x("204e,y100")xc4  f  Max. tractive effort

 0787  + 0000 64 0465
 0788  + 0000 02 6000
 0789  + 0000 64 0110
 0790  + 0100 21 3260
 0791  + 6000 21 3600
 0792  + 0461 21 3600
 0793  + 0000 02 0112

10sy103=(336.13445xy104xc2)/c1    f  Transmission rpm

 0794  + 0000 64 0462
 0795  + 0000 02 6000
 0796  + 0000 64 0463
 0797  + 0114 21 3600
 0798  + 0000 30 0800
 0799  + 0000 00 0060
```

```
0800  + 7019 21 3600
0801  + 6000 21 3596
0802  + 0000 02 0113

11rg12,rc11/1.f Decision for auto. or std. transmission

0803  + 0000 64 7018
0804  + 0000 02 6000
0805  + 0000 64 0472
0806  + 6000 21 3584
0807  + 0000 15 7011
0808  + 0000 73 7017
0809  + 0000 28 7011
0810  + 0000 20 0674

0g21f Go statement

0811  + 0000 20 0683

12sy105=y103xci3   f Engine rpm

0812  + 0000 72 0003
0813  - 0000 64 0461
0814  + 0113 21 3600
0815  + 0000 02 0115
0816  + 0000 30 0820
0817  - 0000 00 0000
0818  + 5110 00 0000
0819  + 5333 61 3445

13rg16,ry105/=c7    f Decision for transmission shift

0820  + 0000 64 0468
0821  + 0000 02 6000
0822  + 0000 64 0115
0823  + 6000 21 3584
0824  + 0000 15 7027
0825  + 0000 73 7019
0826  + 0000 28 7028
0827  + 0000 20 0678

15si3=i3+1     f Index std. transmission
                 ratio to next gear
0828  + 0000 30 0836
0829  + 0000 74 0003
0830  + 2000 29 3360
0831  + 0000 02 0003
```

```
0si4=i4+1f  Index std. transmission
            efficiency to next value

 0832  + 0000 64 7018
 0833  + 0000 74 0004
 0834  + 2000 29 3360
 0835  + 0000 20 1308

14rg19,ri3/(80+i5) f  Test for last transmission ratio

 0836  + 0000 64 0005
 0837  + 0000 30 0840
 0838  + 0000 00 0001
 0839  - 0000 00 0000

 0840  + 0000 74 7019
 0841  + 2000 29 3360
 0842  + 0000 02 6000
 0843  + 0000 64 0003
 0844  + 0000 75 6000
 0845  + 1000 29 3360
 0846  + 0000 15 7050
 0847  + 0000 73 7018
 0848  + 0000 28 7050
 0849  + 0000 20 0681

16rg69,ry105/=c6    f  Test for max. engine speed

 0850  + 0000 64 0467
 0851  + 0000 02 6000
 0852  + 0000 64 0115
 0853  + 6000 21 3584
 0854  + 0000 15 1322
 0855  + 0000 73 7018
 0856  + 0000 28 1320
 0857  + 0000 30 0860
 0858  - 0000 00 0000
 0859  + 0000 00 0080

 0860  + 0000 20 0731

0g42f Go statement

 0861  + 0000 20 0704

19sy105=y103xci3   f  New engine speed

 0862  + 0000 72 0003
 0863  - 0000 64 0461
 0864  + 0113 21 3600
 0865  + 0000 20 1305
```

```
17sy114=y114+c10   f Time adjust while shifting

 0866  + 0000 64 0471
 0867  + 0124 21 3580
 0868  + 0000 02 0124

18sy116=y116+(y104xc10) f Distance adjust while shifting

 0869  + 0000 64 0471
 0870  + 0114 21 3600
 0871  + 0126 21 3580
 0872  + 0000 02 0126

69sy107="401e,y105,0,1" f Find engine torque
                           from engine rpm

 0873  + 0000 64 7019
 0874  + 0000 02 3960
 0875  + 0000 64 7018
 0876  + 0000 02 3961
 0877  + 0000 30 0880
 0878  - 0000 00 0000
 0879  + 0000 00 0001
 0880  + 0000 64 0115
 0881  + 0300 21 3380
 0882  + 0000 02 0117

20sy106=y107xci3xci4    f Transmission torque

 0883  + 0000 72 0004
 0884  - 0000 64 0461
 0885  + 0000 72 0003
 0886  + 0461 21 3602
 0887  + 0117 21 360C
 0888  + 0000 02 0116

0g24f Go statement

 0889  + 0000 20 0686

21rg29,ry103/=c5    f Test for max. transmission rpm

 0890  + 0000 64 0466
 0891  + 0000 02 6000
 0892  + 0000 64 0113
 0893  + 6000 21 3584
 0894  + 0000 15 7097
 0895  + 0000 73 7019
 0896  + 0000 38 0900
 0897  + 0000 20 0691
 0898  + 0000 30 0900
```

```
 0899  - 0000 00 0000

0g42f Go statement

 0900  + 0000 20 0704

29rg22,ry103/ci2   f  Decision to shift gears

 0901  + 0000 72 0002
 0902  - 0000 64 0461
 0903  + 0000 02 6000
 0904  + 0000 64 0113
 0905  + 6000 21 3584
 0906  + 0000 15 7010
 0907  + 0000 73 7019
 0908  + 0000 28 7010
 0909  + 0000 20 0684

30si2=i2+1     f  Index shift speeds

 0910  + 0000 64 7018
 0911  + 0000 74 0002
 0912  + 2000 29 3360
 0913  + 0000 02 0002

31si3=i3+1     f  Index transmission ratio

 0914  + 0000 64 7018
 0915  + 0000 74 0003
 0916  + 2000 29 3360
 0917  + 0000 30 0920
 0918  + 0000 00 0001
 0919  - 0000 00 0000

 0920  + 0000 02 0003

22sy105="401e,y103,0,2" f Eng. speed

 0921  + 0000 64 7019
 0922  + 0000 02 3960
 0923  + 0000 64 7018
 0924  + 0000 02 3961
 0925  + 0000 64 0113
 0926  + 0300 21 3380
 0927  + 0000 02 0115

23sy106="401e,y103,0,1" f Transmission torque

 0928  + 0000 64 7017
 0929  + 0000 02 3960
 0930  + 0000 64 7018
```

```
 0931  + 0000 02 3961
 0932  + 0000 64 0113
 0933  + 0300 21 3380
 0934  + 0000 02 0116
 0935  + 0000 30 0940
 0936  + 2000 29 3505
 0937  + 0000 00 0001
 0938  - 0000 00 0000
 0939  + 0000 00 0002

24sy108="401e,y104,3,4" f  Unit rolling resistance

 0940  + 0000 64 7019
 0941  + 0000 02 3960
 0942  + 0000 64 7018
 0943  + 0000 02 3961
 0944  + 0000 64 0114
 0945  + 0300 21 3380
 0946  + 0000 02 0118

25sy108=(y108xc0)/2000. f Rolling resistance
                          due to motion
 0947  + 0000 64 7017
 0948  + 0000 02 6000
 0949  + 0000 64 0461
 0950  + 0118 21 3600
 0951  + 6000 21 3596
 0952  + 0000 02 0118

26sy108=y108+y101  f  Total rolling resistance

 0953  + 0000 64 0111
 0954  + 0118 21 3580
 0955  + 0000 02 0118
 0956  + 0000 30 0960
 0957  + 5420 00 0000
 0958  + 0000 00 0003
 0959  + 0000 00 0004

27sy109=y106xc2xc3 f  Sprocket torque

 0960  + 0000 64 0464
 0961  + 0463 21 3600
 0962  + 0116 21 3600
 0963  + 0000 02 0119

28sy110=(y109x24.)/c1   f  Tractive effort

 0964  + 0000 64 0462
 0965  + 0000 02 6000
 0966  + 0000 64 7019
```

```
0967  + 0119 21 3600
0968  + 6000 21 3596
0969  + 0000 02 0120

37rg32,ry110/=y102  f  Decision for printout

0970  + 0000 64 0112
0971  + 0000 02 6000
0972  + 0000 64 0120
0973  + 6000 21 3584
0974  + 0000 15 1325
0975  + 0000 73 7018
0976  + 0000 28 1323
0977  + 0000 30 0980
0978  - 0000 00 0000
0979  + 5224 00 0000

0980  + 0000 20 0694

38sy110=y102  f  Index for next printout

0981  + 0000 64 0112
0982  + 0000 02 0120

32sy111=(c0x(c8+(.0025x( c2xci3)p2)))/32.1740  f  Equivalent
                                                  mass
0983  + 0000 64 7019
0984  + 0000 02 6000
0985  + 0000 64 7018
0986  + 0000 02 6003
0987  + 0000 72 0003
0988  - 0000 64 0461
0989  + 0463 21 3600
0990  + 0000 72 6003
0991  + 0000 02 6019
0992  + 0000 64 7017
0993  + 0000 20 7095
0994  + 6019 21 3600
0995  + 0000 22 7094
0996  + 0000 30 1000
0997  + 5110 00 0000
0998  + 0000 00 0002
0999  + 5232 17 4000

1000  + 7019 21 3600
1001  + 0469 21 3580
1002  + 0461 21 3600
1003  + 6000 21 3596
1004  + 0000 02 0121
```

```
33sy117=y110+(-y108)    f Drawbar pull

 1005  + 0000 64 0118
 1006  + 0000 02 6019
 1007  + 0000 65 6019
 1008  + 0120 21 3580
 1009  + 0000 02 0127

34sy112=y117/y111  f  Acceleration

 1010  + 0000 64 0121
 1011  + 0000 02 6000
 1012  + 0000 64 0127
 1013  + 6000 21 3596
 1014  + 0000 02 0122

35sy113=(1.4666667xc9)/y112  f  Δ t

 1015  + 0000 64 0122
 1016  + 0000 02 6000
 1017  + 0000 64 0470
 1018  + 0000 30 1020
 1019  + 4825 00 0000

 1020  + 7019 21 3600
 1021  + 6000 21 3596
 1022  + 0000 02 0123

36sy115=(y104+(c9/2.))xy113x1.4666667  f  Δ d

 1023  + 0000 64 7019
 1024  + 0123 21 3600
 1025  + 0000 02 6000
 1026  + 0000 64 7018
 1027  + 0000 02 6002
 1028  + 0000 64 0470
 1029  + 6002 21 3596
 1030  + 0114 21 3580
 1031  + 6000 21 3600
 1032  + 0000 02 0125

39rg40,ry104/y118  f  Decision for printout

 1033  + 0000 64 0128
 1034  + 0000 02 6000
 1035  + 0000 64 0114
 1036  + 6000 21 3584
 1037  + 0000 30 1040
 1038  + 5120 00 0000
 1039  + 5114 66 6667
```

```
1040  + 0000 15 7044
1041  + 0000 73 7019
1042  + 0000 28 7044
1043  + 0000 20 0702

41sy118=y118+c12   f Index printout interval

1044  + 0000 64 0473
1045  + 0128 21 3580
1046  + 0000 02 0128

0g42f Go statement

1047  + 0000 20 0704

40rg42,ry112/0.    f Test for negative acceleration

1048  + 0000 64 7019
1049  + 0000 02 6000
1050  + 0000 64 0122
1051  + 6000 21 3584
1052  + 0000 15 7056
1053  + 0000 73 7019
1054  + 0000 28 7056
1055  + 0000 20 0704

0g46f Go statement

1056  + 0000 20 0708
```

Printout

```
42e"400e,y104,y114,y116,y103,y105,y109,y110,y108,y117,y112,ci
                        3"  f

1057  + 0000 72 0003
1058  + 0000 30 1060
1059  - 0000 00 0000

1060  r 0000 64 0461
1061  + 0000 02 3960
1062  + 0000 64 0122
1063  + 0000 02 3961
1064  + 0000 64 0127
1065  + 0000 02 3962
1066  + 0000 64 0118
1067  + 0000 02 3963
1068  + 0000 64 0120
1069  + 0000 02 3964
1070  + 0000 64 0119
1071  + 0000 02 3965
1072  + 0000 64 0115
```

```
 1073  + 0000 02 3966
 1074  + 0000 64 0113
 1075  + 0000 02 3967
 1076  + 0000 64 0126
 1077  + 0000 02 3968
 1078  + 0000 64 0124
 1079  + 0000 30 1080

 1080  + 0000 02 3969
 1081  + 0000 64 0114
 1082  + 1100 21 3460

43syi6=y104   f Velocity storage

 1083  + 0000 64 0114
 1084  + 0000 72 0006
 1085  - 0000 02 0010

44syi7=y114   f Time storage

 1086  + 0000 64 0124
 1087  + 0000 72 0007
 1088  - 0000 02 0010

45syi8=y116   f Distance storage

 1089  + 0000 64 0126
 1090  + 0000 72 0008
 1091  - 0000 02 0010

0g49f Go statement

 1092  + 0000 20 0711

46sy114=y114+y113  f Time

 1093  + 0000 64 0123
 1094  + 0124 21 3580
 1095  + 0000 02 0124

47sy116=y116+y115  f Distance

 1096  + 0000 64 0125
 1097  + 0126 21 3580
 1098  + 0000 02 0126
 1099  + 0000 30 1100

48sy104=y104+c9    f Velocity

 1100  + 0000 64 0470
 1101  + 0114 21 3580
```

```
 1102  + 0000 02 0114

0g10f Go statement

 1103  + 0000 20 0672

49si6=i6+1     f Index velocity storage

 1104  + 0000 64 7019
 1105  + 0000 74 0006
 1106  + 2000 29 3360
 1107  + 0000 02 0006

50si7=i7+1     f Index time storage

 1108  + 0000 64 7019
 1109  + 0000 74 0007
 1110  + 2000 29 3360
 1111  + 0000 02 0007

51si8=i8+1     f Index distance storage

 1112  + 0000 64 7019
 1113  + 0000 74 0008
 1114  + 2000 29 3360
 1115  + 0000 02 0008

0si9=i6  f Index storage

 1116  + 0000 64 0006
 1117  + 0000 02 0009
 1118  + 0000 30 1120
 1119  + 0000 00 0001

52rg53,rc11/1.f Transmission decision

 1120  + 0000 64 7019
 1121  + 0000 02 6000
 1122  + 0000 64 0472
 1123  + 6000 21 3584
 1124  + 0000 15 7026
 1125  + 0000 73 7018
 1126  + 0000 28 7028
 1127  + 0000 20 0715

54rg55,ry103/=c5     f Max. transmission
                       printout decision

 1128  + 0000 64 0466
 1129  + 0000 02 6000
 1130  + 0000 64 0113
 1131  + 6000 21 3584
```

```
 1132  + 0000 15 7035
 1133  + 0000 73 7018
 1134  + 0000 28 7036
 1135  + 0000 20 0717

0g56f Go statement

 1136  + 0000 20 0718
 1137  + 0000 30 1140
 1138  - 0000 00 0000
 1139  + 5110 00 0000

53rg55,ry105/=c6     f Max. engine printout decision

 1140 + 0000 64 0467
 1141 + 0000 02 6000
 1142 + 0000 64 0115
 1143 + 6000 21 3584
 1144 + 0000 15 7047
 1145 + 0000 73 7019
 1146 + 0000 28 7048
 1147 + 0000 20 0717

0g56f Go statement

 1148 + 0000 20 0718

55rg56,ry112/0.      f Test for negative acceleration

 1149 + 0000 64 7019
 1150 + 0000 02 6000
 1151 + 0000 64 0122
 1152 + 6000 21 3584
 1153 + 0000 15 7057
 1154 + 0000 73 7019
 1155 + 0000 28 7057
 1156 + 0000 20 0718

0g46f Go statement

 1157 + 0000 20 0708
 1158 + 0000 30 1160
 1159 - 0000 00 0000

56e"7e,500"    f Automatic tape feed

 1160 + 0000 64 7019
 1161 + 0100 21 3500

57si6=i6+(-1) f Index plotter iteration
```

```
1162  + 0000 64 7018
1163  + 0000 02 6019
1164  + 0000 65 6019
1165  + 0000 74 0006
1166  + 2000 29 3360
1167  + 0000 02 0006

58si7 =i7 +(-1)  f Index plotter iteration

1168  + 0000 64 7018
1169  + 0000 02 6019
1170  + 0000 65 6019
1171  + 0000 74 0007
1172  + 2000 29 3360
1173  + 0000 02 0007

60e"410e,0,yi7,yi6,c13,c14"  f Plotter printout

1174  + 0000 64 0475
1175  + 0000 02 3960
1176  + 0000 64 0474
1177  + 0000 30 1180
1178  + 0000 00 0001
1179  + 0000 00 0500

1180  + 0000 02 3961
1181  + 0000 72 0006
1182  - 0000 64 0010
1183  + 0000 02 3962
1184  + 0000 72 0007
1185  - 0000 64 0010
1186  + 0000 02 3963
1187  + 0000 64 7019
1188  + 0500 21 3520

63rg71,ri6/151f  Test further iterations

1189  + 0000 64 7018
1190  + 0000 02 6000
1191  + 0000 64 0006
1192  + 0000 75 6000
1193  + 1000 29 3360
1194  + 0000 15 1326
1195  + 0000 73 7019
1196  + 0000 28 1326
1197  + 0000 30 1200
1198  + 0000 00 0151
1199  - 0000 00 0000

1200  + 0000 20 0733
```

```
0g57f Go statement

 1201  + 0000 20 0719

71e"7e,500"   f  Automatic tape feed

 1202  + 0000 64 7019
 1203  + 0100 21 3500

0si8=350 f

 1204  + 0000 64 7018
 1205  + 0000 02 0008

74e"410e,0,yi8,yi6,c15,c14"  f  Plotter printout

 1206  + 0000 64 0475
 1207  + 0000 02 3960
 1208  + 0000 64 0476
 1209  + 0000 02 3961
 1210  + 0000 72 0006
 1211  - 0000 64 0010
 1212  + 0000 02 3962
 1213  + 0000 72 0008
 1214  - 0000 64 0010
 1215  + 0000 02 3963
 1216  + 0000 30 1220
 1217  + 0000 30 1200
 1218  + 0000 00 0350
 1219  + 0000 00 0500

 1220  + 0000 64 7019
 1221  + 0500 21 3520

72si6=i6+1    f  Index plotter iteration

 1222  + 0000 64 7018
 1223  + 0000 74 0006
 1224  + 2000 29 3360
 1225  + 0000 02 0006

73si8=i8+1    f  Index plotter iteration

 1226  + 0000 64 7018
 1227  + 0000 74 0008
 1228  + 2000 29 3360
 1229  + 0000 02 0008

75rg65,ri6z(i9)+1  f  Test for further iterations
```

```
 1230  + 0000 64 7018
 1231  + 0000 02 6000
 1232  + 0000 64 0009
 1233  + 0000 74 6000
 1234  + 5000 29 3360
 1235  + 0000 02 6000
 1236  + 0000 64 0006
 1237  + 0000 30 1240
 1238  + 0000 00 0001
 1239  - 0000 00 0000

 1240  + 0000 75 6000
 1241  + 1000 29 3360
 1242  + 0000 04 7044
 1243  + 0000 20 0727

0g74f Go statement

 1244  + 0000 20 0736

65e"7e,500"   f  Automatic tape feed

 1245  + 0000 64 7019
 1246  + 0100 21 3500

0si8=350 f Computer preparation

 1247  + 0000 64 7018
 1248  + 0000 02 0008

61e"410e,0,yi7,yi8,c13,c15"  f Plotter printout

 1249  + 0000 64 0476
 1250  + 0000 02 3960
 1251  + 0000 64 0474
 1252  + 0000 02 3961
 1253  + 0000 72 0008
 1254  - 0000 64 0010
 1255  + 0000 02 3962
 1256  + 0000 72 0007
 1257  + 0000 30 1260
 1258  + 0000 00 0350
 1259  + 0000 00 0500

 1260  - 0000 64 0010
 1261  + 0000 02 3963
 1262  + 0000 64 7019
 1263  + 0500 21 3520

0si8=i8+1f Index plotter iteration
```

```
 1264  + 0000 64 7018
 1265  + 0000 74 0008
 1266  + 2000 29 3360
 1267  + 0000 02 0008

0si7=i7+1f Index plotter iteration

 1268  + 0000 64 7018
 1269  + 0000 74 0007
 1270  + 2000 29 3360
 1271  + 0000 02 0007

0rg64,ri7zi9+101   f Test for further iteration

 1272  + 0000 64 7017
 1273  + 0000 74 0009
 1274  + 2000 29 3360
 1275  + 0000 02 6000
 1276  + 0000 30 1280
 1277  + 0000 00 0101
 1278  + 0000 00 0001
 1279  - 0000 00 0000

 1280  + 0000 64 0007
 1281  + 0000 75 6000
 1282  + 1000 29 3360
 1283  + 0000 04 7085
 1284  + 0000 20 0726

0g61f Go statement

 1285  + 0000 20 0723

64e"7e,500"   f Automatic tape feed

 1286  + 0000 64 7019
 1287  + 0100 21 3500

66si1=i1+1    f Index slope subscripts

 1288  + 0000 64 7018
 1289  + 0000 74 0001
 1290  + 2000 29 3360
 1291  + 0000 02 0001

67rg68,rci1z0.f Test for last run

 1292  + 0000 64 7017
 1293  + 0000 02 6000
 1294  + 0000 72 0001
```

```
1295  - 0000 64 0461
1296  + 0000 30 1300
1297  - 0000 00 0000
1298  + 0000 00 0001
1299  + 0000 00 0500

1300  + 6000 21 3584
1301  + 0000 04 7003
1302  + 0000 20 0730

0g1 f Go statement

1303  + 0000 20 0663

68h f Halt

1304  + 0000 08 0000
1305  + 0000 02 0115
1306  + 0000 64 0838
1307  + 0000 30 0829
1308  + 0000 02 0004
1309  + 0000 30 0866
1310  + 0000 00 0000
1311  + 0000 00 0000
1312  + 0000 00 0000
1313  + 0000 00 0000
1314  + 0000 00 0000
1315  + 0000 00 0000
1316  + 0000 00 0000
1317  + 0000 00 0000
1318  + 0000 00 0000
1319  + 0000 00 0000

block dict

1320  + 0000 37 0860
1321  + 0000 20 7061
1322  + 0000 30 0860
1323  + 0000 37 0980
1324  + 0000 20 7081
1325  + 0000 30 0980
1326  + 0000 37 1200
1327  + 0000 20 7001
```

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